VENTILATION MEASURES IN SINGLE-FAMILY HOUSES WITH HIGH RADON CONCENTRATIONS

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Abstract

Examples of ventilation systems installed in existing single-family houses with high radon concentrations are given in this paper. The radon originates from the building material in one of the houses and from the soil in the others. Measurements show that the radon concentration has decreased to an acceptable level in all these houses after installation of the ventilation systems.

Introduction

High levels of radon have been found in many dwellings in Sweden. However, the problem can often be solved by relatively simple ventilation measures. This is true both in houses where the radon originates from the building material and in houses where it originates from the soil.

Increasing the rate of air charge by means of mechanical supply and exhaust ventilation systems is a standard solution applied to houses in which the radon originates from the building material. To minimize the energy consumption, heat is usually recovered from the exhaust air by means of heat exchangers. It is also important that the ventilation systems are balanced for as low as possible negative pressures indoors, as a certain additional leakage of radon from the soil cannot be excluded.

If the radon originates from the surrounding soil, special measures must usually be taken from case to case, depending on the construction of the building and the nature of the soil. A common solution is to extract the radon from the soil below the foundations by means of a special exhaust ventilation system. Another solution, which is mainly applicable to houses built on gravel ridges, is to extract the radon from a well in the soil near the house.

The importance of ventilation

In a building made of a specific material, the radon concentration is determined by the rate of air change. Swedish building standards specify a rate of air change of $0.5 h^{-1}$ in residential houses with mechanical ventilation. If this rate of air change is maintained, the radon content will usually be acceptable. However, higher rates of air change may be necessary in houses made of shale-based lightweight concrete and in houses built on soil with a relatively high content of radium.

The radon concentration in the indoor air can be assumed to be inversely proportional to the rate of air change. In houses with normal rates of air change (about $0.5 h^{-1}$), the radon daughter concentration is appreciably lower than the radon concentration, i.e. usually about 50% of the radon gas concentration. On the other hand, at very low rates of air change, the radon daughter concentration will increase to almost the same value as the radon content. As the radon daughter concentration is most serious from hygienic considerations, there is thus every reason to ensure that the ventilation rate is not too low.

In single-family houses, the radon concentration may vary widely from one room to the next due to differences, for instance, in the wall materials. To reduce the radon daughter concentration to acceptable values, it must be possible to vary the rates of air change individually in the rooms. This calls for mechanical supply and exhaust air ventilation. The required rate of air change can then also be maintained independently of the weather conditions. An example of how the supply and exhaust air flows can be distributed in a single-level house at a normal rate of air change of $0.5 h^{-1}$ is shown in Fig. 1.

Increased ventilation rates

Mechanical supply and exhaust air ventilation systems have been installed by Fläkt in many single-family houses in Sweden with high radon concentrations. Two examples of such installations are given here. After installation of the ventilation systems, the radon concentrations in these houses have decreased to levels below 70 Bq/m^3, i.e. the value recommended in Sweden for new houses.

One installation was made in Umeå (in the north of Sweden), in a semi-detached single-family house (house A), adjoining a similar house (house B). Shale-based lightweight concrete had been used in the walls of these houses, which were built in 1967. Measurements, made by Umeå University (2), had shown that the radon daughter concentration was rather high in these houses before the installation, i.e. about 295 Bq/m^3 in house A and about 340 Bq/m^3 in house B, determined according to the Kusnetz method.

After the installation of a REXOVENT mechanical supply and exhaust air ventilation system with heat recovery in house A, the radon daughter concentration dropped to about 45 Bq/m^3 (see Fig. 2). During the same time, the concentration in house B was still at a fairly high level, i.e. about 320 Bq/m^3. The same type of ventilation system installed later in house B reduced the radon daughter level to about 50 Bq/m^3.

Another installation of a mechanical ventilation system has been made in a single-family house in Tidaholm (in the south-west of Sweden). In this case, the radon gas enters the house by diffusion through the walls in the basement, as the soil surrounding the house contains burnt shale with a high radium content. This resulted in very high radon concentrations in the basement of the house, and also increased levels on the ground floor. A comprehensive research programme, supported by the Swedish Council for Building Research, was carried out in this house.

It was first decided to measure the radon daughter concentrations in some of the rooms at an air change rate of 0.5 h^{-1} on the ground floor and various air change rates (0.5 - 3 h^{-1}) in the basement. A mechanical ventilation system was therefore installed. Heat was recovered from the exhaust air by a rotary heat exchanger. The variation of the radon daughter concentration with the ventilation rate in the room with highest concentration is shown in Fig. 3. Also in this room, an acceptable level can be reached if the ventilation rate is increased to 2-3 h^{-1}.

At a later stage of the research programme, most of the radioactive soil surrounding the house was removed. The radon daughter concentration was then considerably below 70 Bq/m^3 in all rooms at normal ventilation rates in the house (0.5 h^{-1}).

Extraction of radon from the soil

In several parts of Sweden, radon from the soil has resulted in high levels of radon indoors. This is particularly true for houses built on gravel ridges. To solve the problem, the first step is to try to prevent the radon from leaking into the house. A special ventilation system which extracts the radon from the surrounding soil, can be installed for this purpose. Two such installations, carried out by Fläkt, will be mentioned here.

Radon daughter concentrations between 1800 and 9600 Bq/m^3 were measured (1) in a single-family house built on a gravel ridge in Sollentuna, near Stockholm. A considerable part of the radon was found to leak into the house through an untight inspection hatch. After sealing this hatch, the radon daughter concentration was reduced to about 1000 Bq/h at an air change rate in the house of about 0.5 h^{-1}.

An extraction system for ventilation of the foundation was then installed. A 10 cm diameter opening was made in the floor in the basement and a spiral duct and an exhaust fan were connected to this opening. The fan gives a sub-atmospheric pressure below the floor in the basement of about 80 Pa, which prevents radon from leaking into the house. After the installation of the fan, the radon daughter concentration was reduced to about 200 Bq/m^3. The remaining content probably largely originates from the lightweight concrete in the walls and can be reduced by increased air change rates in the dwelling areas, using a mechanical supply and exhaust air ventilation system.

Another solution which can be applied mainly to houses built on gravel ridges has been investigated in four houses in Valbo, near Gävle (about 200 km north of Stockholm). Radon is extracted here from a well in the ground by means of a 2.3 kW fan. The well has a diameter of 0.8 m and is 4 m deep. It is situated 10 to 60 m from the houses in question. After the installation of the fan, the radon daughter concentrations in these houses have decreased from typical values of about 1000-2000 Bq/m^3 to about 50 Bq/m^3.

Conclusions

The installation examples given here show that the radon concentration in existing single-family houses can be reduced considerably by fairly simple ventilation measures. Even in houses with the highest known levels, it is usually possible to reduce the concentration below 70 Bq/m^3, i.e. the value redommended in Sweden for new houses.

References

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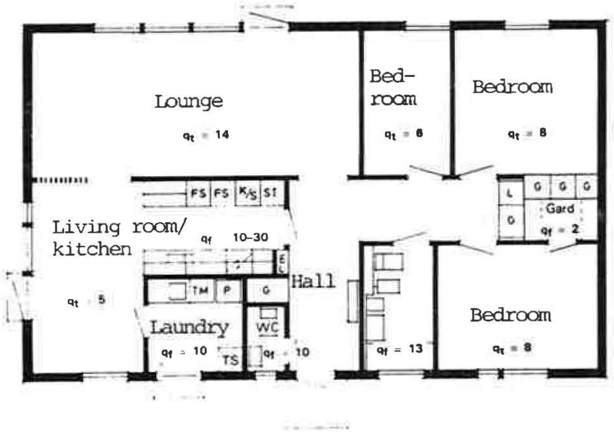

Fig. 1. Examples of the supply and exhaust air flows in a single-level house (q_t = supply air flow, l/s and q_f = exhaust air flow, l/s).

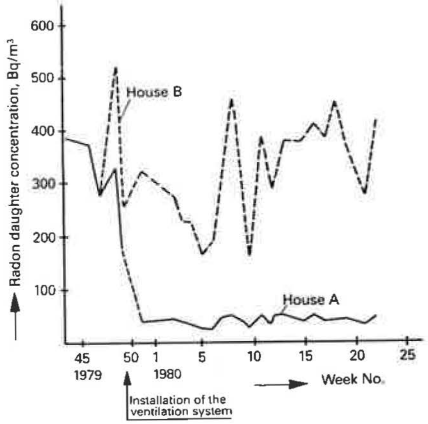

Fig. 2. Measured radon daughter concentrations in house A and house B. (Installation in Umeå.)

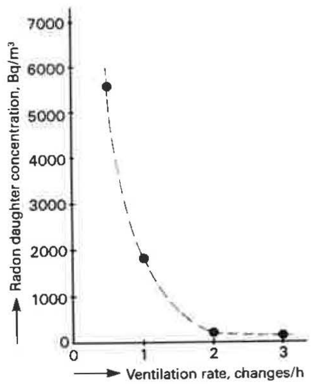

Fig. 3. Measured radon daughter concentration in the room with highest concentration. (Installation in Tidaholm.)

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